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STUDIES ON WESTERN AUSTRALIAN PERMIAN BRACHIOPODS 7. THE STROPHALOSIID GENERA *WYNDHAMIA* BOOKER, 1929, *LIALOSIA* MUIR-WOOD AND COOPER, 1960 AND *LIVERINGIA* GEN. NOV.

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Abstract: Strophalosiid brachiopods of the genera *Wyndhamia, Lialosia* and *Liveringia* gen. nov., from the Permian sequences of Western Australia, are revised and described. The new genus *Liveringia* is diagnosed and the following species described or revised: *Wyndhamia colemani* sp. nov., *Wyndhamia multispinifera* (Prendergast), *Lialosia kimberleyensis* (Prendergast) and *Liveringia magnifica* gen. et. sp. nov. Additional material referred to *Wyndhamia* with a query is briefly described and figured.

Specimens from the Bowen Basin, Queensland and from New Zealand, previously assigned to the Western Australian species *Echinalosia prideri* (Coleman), are assigned to *Echinalosia denisoni* sp. nov.

Strophalosiid brachiopods are abundant in the marine Permian faunas of Western Australia. This paper continues the series of studies on Western Australian Permian brachiopods (Archbold 1986) and documents the remainder of the representatives of the family Strophalosiidae. The strophalosiids described herein come from various Permian stratigraphical horizons within the Perth, Carnarvon, Canning and Bonaparte Gulf Basins (Archbold 1981, fig. 1). The Permian stratigraphy of these basins is documented in references referred to in Archbold (1981, p. 109) and the basis for age assignment of species and correlations is the same as that utilized in recent studies of Western Australian Permian spiriferid brachiopods (Archbold & Thomas 1985, 1986a, fig. 2).

Several of the species described herein are useful for interbasinal correlation, notably *Wyndhamia colemani* sp. nov., *W. multispinifera* (Prendergast) and *Lialosia kimberleyensis* (Prendergast). Terminology is standard as in previous studies and follows that used by Muir-Wood (1965) and Sarycheva (1970).

COLLECTIONS

All figured and measured specimens are housed in the following institutions as indicated by the prefix to the registered numbers. CPC—Commonwealth Palaeontological Collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. GSWA—Geological Survey of Western Australia, Perth, Western Australia.

All figured specimens of new species, other than holotypes, are paratypes.

SYSTEMATIC PALAEONTOLOGY

Order Productida Sarycheva & Sokolskaya 1959
Suborder Strophalosiidina Waterhouse 1975
Superfamily Strophalosiacea Schuchert 1913
Family Strophalosiidae Schuchert 1913
Subfamily Strophalosiinae Schuchert 1913

Discussion: The subfamilial and familial classification of strophalosiid brachiopods has been outlined in Archbold (1986) and will not be repeated here. This paper describes representatives of the genera *Wyndhamia* Booker (1929), *Lialosia* Muir-Wood and Cooper (1960) and *Liveringia* gen. nov.

Genus **Wyndhamia** Booker, 1929
= *Branxtonia* Booker, 1929

Type Species: *Wyndhamia dalwoodensis* Booker (1929), from the Elderslie Formation, near Branxton, New South Wales, by original designation (see McClung 1983, p. 73).

Discussion of Type Species: The lectotype, a ventral valve internal mould (Australian Museum F41767) was selected by Waterhouse (1964, p. 50) and figured by Booker (1929, pl. 1, fig. 2). As noted by Clarke (1970a, p. 42) selection of AMF 41767 has ensured stable nomenclature. Booker (1929) originally described three species (in the order *W. dalwoodensis, W. valida* and *Branxtonia typica*) which have been regarded as conspecific by subsequent workers (Maxwell 1954, Waterhouse 1964, Clarke 1970a). *Wyndhamia dalwoodensis* is thus the senior subjective synonym of the other two species by page priority within Booker (1929).

Diagnosis: Large, usually subquadrate at maturity, strophalosiids with the dorsal valve thickened anteriorly like a wedge. Spines erect and semi-recumbent on ventral valve, fine and erect on dorsal valve. Dorsal valve also with concentric lamellae and often with elongate dimples. Teeth large. Brachial ridges prominent. Width of posterior shell margin approaches maximum shell width at maturity in many species.

Discussion: *Wyndhamia,* originally proposed as a subgenus of *Strophalosia* by Booker (1929) was accepted as a subgenus by Prendergast (1943, p. 40) and Zavodovskiy (1960a, 1960b) unlike Maxwell (1954) who regarded *Wyndhamia* as a synonym of *Strophalosia.* Muir-Wood and Cooper (1960) differentiated the genus from

Strophalosia on the nature of the spinose ornament of *Wyndhamia* and Muir-Wood (1965) considered that the dorsal valve of *Wyndhamia* was usually dimpled and non-spinose.

Waterhouse (1964, 1969, 1982) stressed the anteriorly, heavily-thickened dorsal valve in his diagnosis of the genus, a feature disputed by Clarke (1970a) who regarded *Echinalosia* Waterhouse (1967) as a junior synonym of *Wyndhamia*. Clarke considered that "a wedge shaped dorsal valve is a natural consequence of strophalosiid morphology where the internal surface of the valve remains almost flat and is geniculated against a short trail, whereas the external surface maintains a fairly even concavity" (Clarke 1970a, p. 21). Clarke subsequently accepted the validity of both *Wyndhamia* and *Echinalosia* (eg. in Clarke & Farmer 1976). McClung (1983, pp. 71, 73) has reviewed the genus and its occurrence in the eastern Australian Permian and listed seven distinct species with two additional subspecies. Waterhouse (1982, p. 128) has summarized occurrences in New Zealand and up to five separate species of *Wyndhamia* may be present in the New Zealand Permian. Two, with a possible third, species of strophalosiids from Western Australia conform to a restricted diagnosis of *Wyndhamia* and hence support the incorporation of the anterior thickening of the dorsal valve in the diagnosis of the genus.

Species of *Echinalosia* Waterhouse share morphological features with species of *Wyndhamia* (McClung 1983). Nevertheless *Echinalosia* are usually smaller and are more circular or subtrigonal in outline than *Wyndhamia* because of the shorter hinge line of *Echinalosia*.

The relationship of *Wyndhamia* to *Pseudostrophalosia* Clarke (1970) requires clarification. *Pseudostrophalosia* was based on two specimens (not one as in Waterhouse 1982, p. 39) one of which is the holotype of *Strophalosia brittoni* Maxwell (1954). The holotype (UQF15657), as clearly stated by Clarke (1970, p. 986), is an internal mould of a ventral valve and possesses dendritic posterior adductor scars. Dendritic posterior ventral adductor scars were stated to be the generic feature of *Pseudostrophalosia* by Clarke (1970a, p. 48) although Waterhouse (1982, p. 39) stated that Clarke did not indicate which valve he was describing. Waterhouse (1978), as alluded to in Archbold (1983, p. 246), indicated that dendritic ventral adductor scars develop late in the ontogeny of the Strophalosiidae as in other productid families. Weakly-dendritic ventral adductor scars are developed in gerontic *Wyndhamia colemani* sp. nov. and so *Wyndhamia* is regarded by me as probably being a senior subjective synonym of *Pseudostrophalosia* as in Waterhouse (1982). Waterhouse (1986b, p. 28) has subsequently indicated that details of the dorsal valve thickening and the ventral ear spines may justify recognition of the genus.

Wyndhamia is morphologically close to the new genus *Liveringia* in terms of size, shape and development, of muscle scars and brachial ridges but details of external ornament readily differentiate the two genera. Both *Liveringia* gen. nov. and a new genus represented by *Wyndhamia circularis* Chang (in Chang & Ching, now Zhang & Jin 1976) are probably descendants of *Wyndhamia*. Zhang's species was referred to by Waterhouse (1983, p. 147) as *Megalosia circularis*. The description of *Megalosia* is currently in press (Waterhouse, pers. comm. 15- 01-87).

Arcticalosia Waterhouse (1986a, p. 2) was differentiated from *Wyndhamia* on the basis of having only one grade of spines over the ventral valve whereas *Wyndhamia* was said to have coarse and fine spines over its ventral valve. However the superbly-preserved Western Australian material illustrated herein indicates that ventral spines may be essentially coarse (as in *W. colemani* sp. nov.) or fine (as in *W. multispinifera*). *Arcticalosia* may be of use as a subgenus of *Wyndhamia*, characterised by fine ventral spines, when the full details of the ventral spine pattern of *W. dalwoodensis*, the type species of *Wyndhamia*, are known.

Generic Distribution: Described species show that the genus has a disjunct (or bipolar) distribution during the Permian. It is known from Asselian/Tastubian to Kazanian faunas of eastern Australian (Clarke 1970a, Dear 1971, 1972); Baigendzhinian to Kazanian faunas of New Zealand (Waterhouse 1982); Baigendzhinian and Kungurian faunas of Western Australia (as described herein); Kazanian faunas of northern Siberia (Taimyr Peninsula) and Early Tatarian faunas of northeastern Siberia (Zavodovskiy 1960a, 1960b, Grigor'eva, 1977); and Kazanian faunas of Arctic Canada (Waterhouse 1967a, 1969).

Wyndhamia colemani sp. nov.
Figs. 1A-P, 2A-N, 3A-F

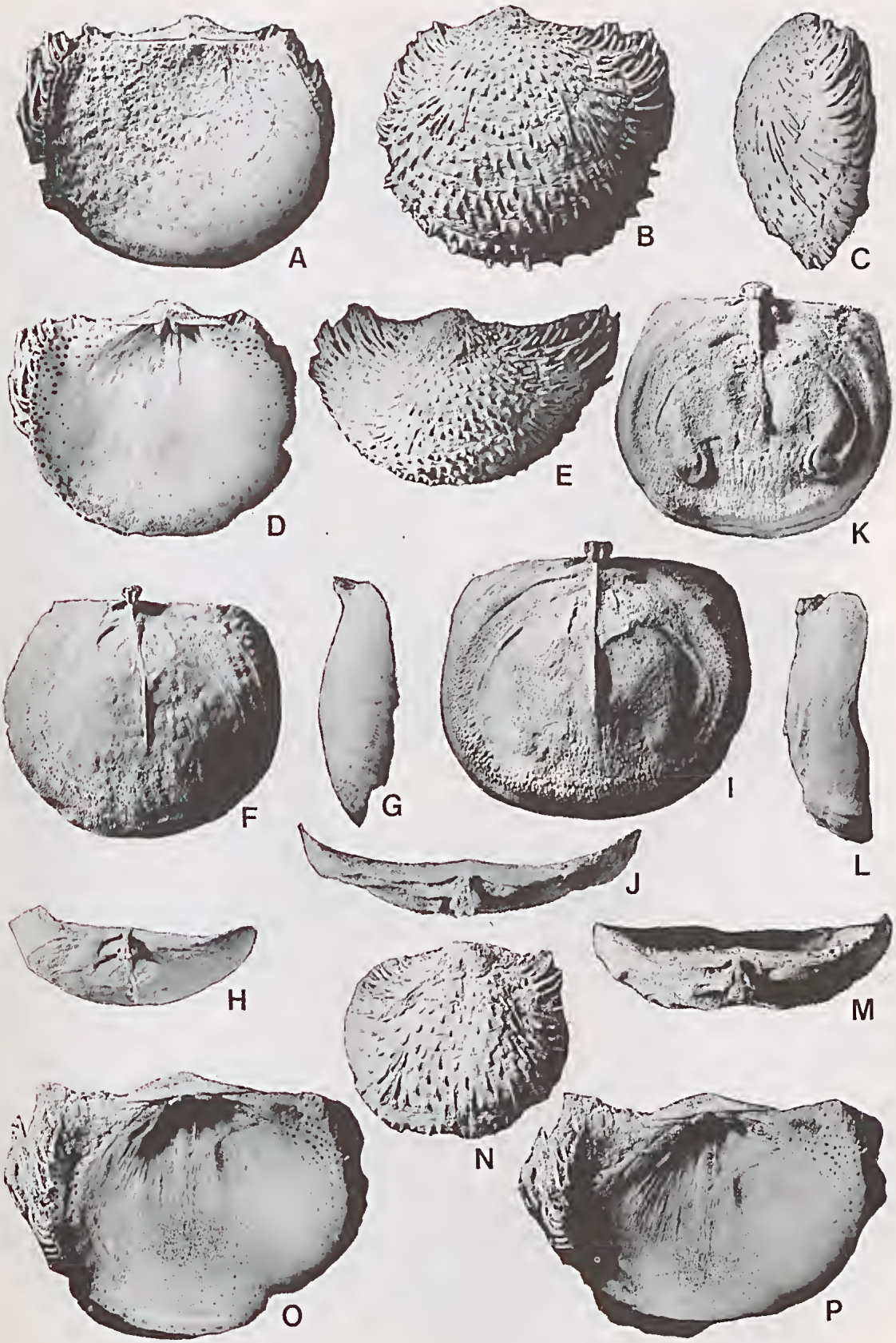
1967 *Strophalosia* sp. nov., Condon, p. 149.
1972 *Strophalosia* sp. Dickins, p. 94.
1976 *Wyndhamia*, Waterhouse, p. 99.
1981 *Wyndhamia* sp. nov., Archbold, p. 121.
1986 *Wyndhamia* sp. nov., Archbold, p. 110.

Etymology: For Dr. P. J. Coleman, substantial contributor to the knowledge of Western Australian Permian Productida.

Holotype: CPC26416, a complete articulated shell from the Madeline Formation, Carnarvon Basin (Fig. 1A-H).

Material, Localities and Age: Specimens as figured and measured in addition to abundant material from the Madeline Formation, Carnarvon Basin, in the collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. CPC24413, 24414, 26416, 26418, 26419, 26421, 26422, 2 complete shells, 2 ventral valves, 2 dorsal valves and an internal mould of a complete shell all from BMR locality WB169, 6.6 km on a bearing of 205° from

Fig. 1—A-P, *Wyndhamia colemani* sp. nov. All from Madeline Formation, Carnarvon Basin. A-H, holotype, CPC 26416, complete shell in dorsal, ventral, lateral, ventral interior, ventral posterior, dorsal interior, dorsal profile and dorsal posterior views, all ×1. I-J, CPC 24413, dorsal valve interior and posterior views, ×1 and ×1.3 respectively. K-M, CPC 24414, dorsal valve interior, profile and posterior views, all ×1.2. N, CPC 26417, shell in ventral view, ×1. O-P, CPC 26418, ventral valve in dorsal and antero-dorsal views, ×1.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Mt. Madeline. CPC26417, 26420, 2 complete shells from BMR locality WB11, 2.4 km on a bearing of 143° from Mt. Madeline. All the above from the upper member of the Madeline Formation (above the levels with *Echinalosia prideri*). Carnarvon Basin (Condon 1967, p. 149). CPC26423-26428, 3 ventral valves and 3 dorsal valves from BMR locality 627/1, Lat. 14°26′, Long. 129°43′, 11.5 km north-north west of Table Hill, Port Keats District, Northern Territory, unnamed limestone, lower marine beds, Port Keats Group, Bonaparte Gulf Basin.

All early Baigendzhinian (Middle Artinskian).

Size Ranges: A total of 17 specimens (including the figured specimens) were measured. Hinge width, 17.8-30.4 mm; maximum width, 33.9-52.5 mm; ventral valve height, 29.4-51.5 mm; dorsal valve height, 26.6-40.6 mm; thickness, 9.3-25.6 mm; ventral valve interarea height, 1.9-3.1 mm; dorsal valve interarea height, 1.1-2.3 mm.

Diagnosis: Large *Wyndhamia,* transversely oval to subquadrate in outline. Ventral valve evenly convex or rarely with shallow sulcus; with abundant body spines. Spines moderately coarse with relatively short spine bases. Dorsal valve concave with distinctly convex internally visceral disc; distinctly geniculate with rounded trail.

Description: Shell large, outline transversely oval to subquadrate. Ventral valve moderately convex with convexity being more pronounced at lateral and anterior margins of valve. Ventral valve usually evenly convex over visceral disc, a few specimens possess distinct, shallow sulcus—best seen in oblique light. Hinge line straight, hinge itself being up to two-thirds maximum width of shell at mid-length of shell. Posterior of valves straight, parallel to hinge; this imparts straight margin, some seven-eighths of maximum shell width, which heightens subquadrate outline of mature shells. Ears developed but not clearly demarcated from remainder of valves. Ventral umbo moderately distinct despite being flattened by umbonal cicatrix (largest measured cicatrix 5.4 mm wide). Ventral interarea distinct, low, considering size of shells, bisected by small delthyrium which is filled by gently convex pseudodeltidium. Ventral interarea striated parallel to hinge line.

Exterior ornamentation of ventral valve consists of spines and concentric growth lamellae; latter best seen on anterior of valve. Spines thickly clustered along hinge, ears and posterior lateral margins where they are erect (at low angle to valve), project beyond margin of shell away from umbo. Posteriorly, spines coarse (up to 1.3 mm thick at base), usually curved; up to 13 mm long, spaced at 6 to 7 per cm on mature shells in 3 or more ill-defined rows. Body spines arranged subquincuncially on juvenile and subinature stages of growth, concentrically on anteriors of mature valves; only slightly finer than corresponding posterior spines but coarsen anteriorly on valve. Body spines relatively numerous (about 20 per cm² at 2 cm from umbo), spine bases normally short. Spine bases up to 1.2 mm wide on anterior of large valves. Body spines long (the longest measured being 7 mm), sub-erect.

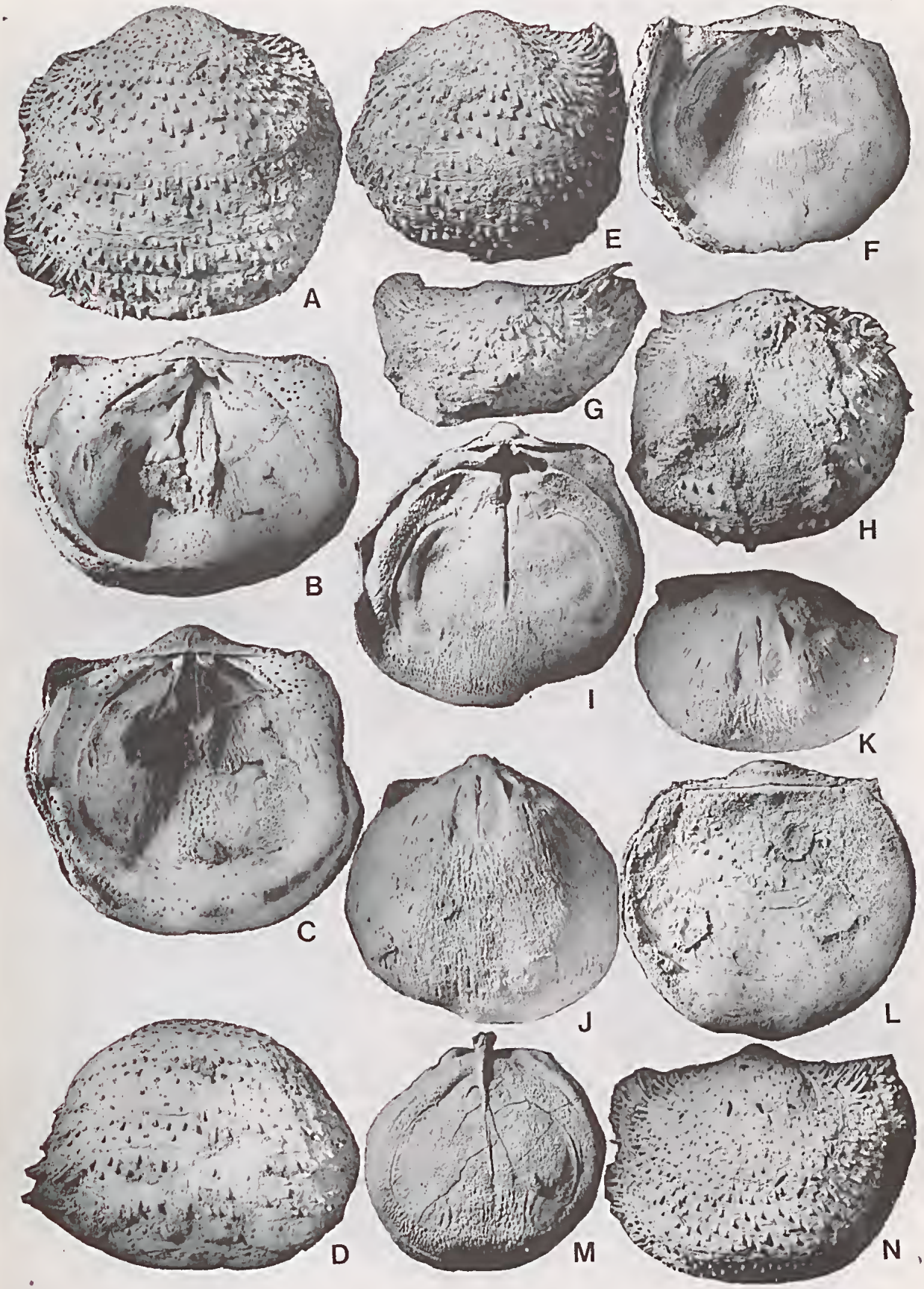
Exterior ornament of dorsal valve consists of distinct, widely-spaced concentric growth lamellae, numerous fine spines and distinct dimples. Spines arranged in concentric rows, fine (thickest spine measured 0.4 mm wide), delicate and up to 3 mm long. Slight decortication of valve (dimples, growth lamellae still present) removes all trace of spines. Dimples tend to be circular, arranged in concentric rows imparting subquincuncial arrangement. Capillae not present on dorsal exterior.

Ventral teeth strong, robust, divergent. Marginal ridge, stepped down from hinge, developed either side of teeth, persists only until alar extremities. Adductor muscle scars elongate, bisected by low median ridge which is higher posteriorly; smooth with faint lines of growth, rarely feebly dendritic anteriorly. Diductor muscle scars large, flabellate, posteriorly smooth, anteriorly densely striated; extend further anteriorly than adductor marks. Remainder of valve finely pitted, striated, with minute pustules developed anteriorly. Trail demarcated from visceral disc by low marginal ridge which trail of dorsal valve fits snugly against. Exterior spines open into valve interior around perimeter of valve.

Dorsal valve geniculate, geniculated angle being curved up to 65° from anterior of distinctly internally convex visceral disc. Dorsal interarea possesses small chilidium. Dorsal adductor scars smooth, bisected by median septum so that each triangular shaped. Anterior components of adductor scars raised above level of visceral disc, posterior components depressed, hence lower than level of visceral disc. Brachial ridges distinct, arise close to anterior of posterior components of adductor scars; broadly semi-circular, hook back sharply at anterior extremities. Region of brachial ridges smooth. Cardinal process strong, erect, extends behind hinge, co-planar with dorsal interarea. Cardinal process quadrilobed interiorly, prominent median lobe divided by deep groove; lateral lobes of process small, may project widely from central lobe. Cardinal process arises from strongly-developed median septum; pair of small marginal ridges run laterally, at small angle to hinge, from process but they do not appear to be significant for support of process. Transversely oval marginal ridge arises at hinge line behind deep, wide sockets; encircles visceral disc. Median septum strong, sharp, high, extends anteriorly for some two-thirds of valve length. Valve finely pustulose between brachial ridges and marginal ridge. Trail of valve minutely pustulose.

Discussion: The above description of *W. colemani* sp. nov. is based on beautifully preserved, articulated shells complete with spinose exteriors. *W. multispinifera* (Prendergast) can be distinguished from *W. colemani* sp. nov. by means of its more rounded outline, somewhat finer and denser ventral spines and its gently concave dorsal

Fig. 2—A-N, *Wyndhamia colemani* sp. nov. All from Madeline Formation, Carnarvon Basin. A-D, N, CPC 26419, ventral valve in ventral, antero-dorsal, dorsal, anterior and posterior views, ×1. E-F, CPC 24414, ventral valve in ventral and dorsal views, ×1. G-H, L, CPC 26420, shell in posterior, ventral and dorsal views, ×1. I-K, CPC 26421, internal mould of shell in dorsal, ventral and posterior views, ×1. M, CPC 26422, dorsal valve interior view, ×1.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valve with a flattish visceral disc. The interior geniculation of the dorsal valve of *W. multispinifera* is much sharper than that of *W. colemani* sp. nov. which is rounded.

Arctic Canadian species of *Wyndhamia* (Waterhouse 1969) possess relatively flat dorsal valves and either a long hinge line or finely spaced, delicate ventral spines as discussed below under *W. multispinifera* and hence are not close to *W. colemani* sp. nov.

Wyndhamia appears to be a feature of Kazanian and younger faunas of north-eastern Siberia and the Taimyr Peninsula (Grigor'eva 1977). *W. gijigensis* Zavodovskiy (1960a) and *W. chivatschensis* Zavadovskiy (1960b, see also Zavadovskiy & Stepanov 1971 and Grigor'eva 1977) are large species, from the Early Tatarian (Chhidruan?) Khivach suite, which may be synonymous (Grigor'eva 1977). The Siberian species are close to *W. colemani* in details of the morphology of the dorsal valve spinosity and concavity (see Grigor'eva 1977, pl. 4, figs 11, 12, 15). *Strophalosia multituberculata* Ustritskiy (1963, in Ustritskiy and Chernyak 1963, p. 96, pl. 22, figs 1-5) may be allied to *Wyndhamia* (Grigor'eva 1977) and comes from the Kazanian of the Taimyr Peninsula. It is a transverse species with a heavily dimpled and finely spinose dorsal valve.

Wyndhamia species are widely known from the Permian of eastern Australia (Booker 1929, Waterhouse 1969, Clarke 1970a, Dear 1971, Clarke & Farmer 1976) and New Zealand (Waterhouse 1964, Waterhouse & Vella 1965, Waterhouse 1982) where species have relatively flat dorsal valves (compared with *W. colemani* sp. nov.) as shown in Booker (1929, pl. 2, figs 1, 2), Clarke (1970a, pl. 8, fig. 5) and Dear (1971, pl. 3, figs 8, 10) for transverse species with outlines closer to that of *W. colemani* sp. nov. and Clarke (1970a, pl. 8, fig. 7) and Dear (1971, pl. 3, figs 1, 3) for species with an elongate outline.

One feature well shown by *W. colemani* sp. nov. is the distinct dimpling of the dorsal valve exterior. This is a characteristic feature of at least some *Wyndhamia* species (see Booker 1929, pl. 1, fig. 5; pl. 3, fig. 7; McClung 1983, fig. 15: 7, 9) and varies from species to species. *W. colemani* sp. nov. has relatively coarse dimples (like those of *W. dalwoodensis* or *W. sphenarctica* Waterhouse, 1969, pl. 8, fig. 13) that are widely spaced (like those of *Wyndhamia antarctica* Frech, 1898, pl. 4, figs 9a, 9b). The dimples of *W. multispinifera* (Prendergast) are much smaller than those of *W. colemani* sp. nov. and are closely spaced. Poorly-preserved specimens from an unnamed limestone of the Bonaparte Gulf Basin, that are referred to *W. colemani* sp. nov. herein, possess the characteristic dimpling of Madeline Formation representatives of the species.

Wyndhamia multispinifera (Prendergast, 1943)
Figs 3G-Q, 4A-F

1943 *Strophalosia clarkei*: Prendergast, p. 42, pl. 15, fig. 4.
1943 *Strophalosia multispinifera* Prendergast, p. 50, pl. 5, figs 6-8.
1957 *Strophalosia multispinifera* Prendergast, Coleman, p. 114, pl. 18, figs 3-14.
1958 *Strophalosia multispinifera* Prendergast, Guppy *et. al.*, p. 48.
1967 *Strophalosia multispinifera* Prendergast, Condon, p. 169.

Holotype: UWA 20458, a worn ventral valve from scarp 3.2 km east of Christmas Creek Homestead, West Kimberley District, Noonkanbah Formation, Canning Basin.

Material, Localities and Age: Specimens as figured and measured in addition to abundant material from the Noonkanbah Formation in the collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. CPC 24412, a submature dorsal valve from BMR locality KNF 73, 3.5 km on a bearing of 288° from Bruten's Old Yard, Cherrabun Station, type section of Noonkanbah Formation at 225 m above base. CPC 24410, 24411, 26432, 2 ventral valves and 1 dorsal valve from BMR locality KNF 76A, 6.9 km at a bearing of 298° from Bruten's Old Yard, Cherrabun Station, type section of Noonkanbah Formation at 357 m above base of formation. CPC 26430, 26431, a ventral valve and 1 dorsal valve from BMR locality KNF 77A, northwest of Bruten's Old Yard, Cherrabun Station, type section of Noonkanbah Formation. All above Canning Basin. CPC 26429, an incomplete dorsal valve from BMR locality G298, 4 km northeast of Black Hill Well, 9 km northeast (approx.) of Walbarune Peak, 62 m above base of Nalbia Sandstone, Carnarvon Basin. Specimens from the Cundlego and Wandgee Formations of the Carnarvon Basin were well figured by Coleman (1957, pl. 18, figs 5-12, 14).

Noonkanbah, Cundlego and Wandagee Formation specimens are Late Baigendzhinian (Late Artinskian). Nalbia Sandstone occurrences are Early Kungurian.

Size Ranges: A total of 31 specimens (including the figured specimens) were measured. Hinge width, 19.5-37.0 mm; maximum width, 33.3-51.9 mm; ventral valve height, 33.2-47.5 mm; dorsal valve height, 27.3-39.2 mm; thickness, 13.3-21.5 mm, ventral valve interarea height, 2.5-3.9 mm; dorsal valve interarea height, 1.8-2.9 mm.

Diagnosis: Large *Wyndhamia,* transverse to subcircular in outline. Ventral valve with median flattening or shallow

Fig. 3—A-F, *Wyndhamia colemani* sp. nov. A-F, from unnamed limestone, Lower Marine Beds, Port Keats Group, Bonaparte Gulf Basin, Northern Territory. A, CPC 26423, ventral valve in ventral view, ×1. B, CPC 26424, ventral valve in ventral view, ×1. C, CPC 26425, decorticated dorsal valve, interior view, ×1. D, CPC 26426, ventral valve in dorsal view, ×1. E, CPC 26427, decorticated dorsal valve, interior view, ×1.2. F, CPC 26428, dorsal valve, interior view, ×1. G-Q, *Wyndhamia multispinifera* (Prendergast). G-K, P-Q, from Noonkanbah Formation, Canning Basin; L-M, from Nalbia Sandstone, Carnarvon Basin. G-H, CPC 24410, ventral valve in ventral and posterior views, ×1. I-K, CPC 24411, ventral valve in dorsal, ventral and antero-dorsal views, ×1. L-M, CPC 26429, dorsal valve, interior and profile views, ×1.2. P-Q, CPC 24412, submature dorsal valve in posterior and internal views, ×1. N-O, *Wyndhamia*? sp. A, from Mingenew Formation, Perth Basin. N-O, GSWAF 11048, internal mould of dorsal valve, ×1.2, latex cast of mould, ×1.3.

Fig. 4 – A-F, *Wyndhamia multispinifera* (Prendergast). All from Noonkanbah Formation, Canning Basin. A, D-E, CPC 26430, ventral valve in ventral, anterior and posterior views, ×1. B, CPC 26432, dorsal valve, interior view, ×1. C, F, CPC 26431, dorsal valve in dorsal and interior views, ×1.

sulcus. Ventral body spines fine, closely spaced with radially elongate spine bases. Dorsal valve gently concave to flattish if transverse, moderately concave if more elongate; low median fold rarely present. Dorsal visceral disc flattish or internally slightly convex. Dorsal valve sharply geniculate at abrupt angle anteriorly.

Description: Shell large with outline transverse to subcircular. Ventral valve moderately convex with convexity being more pronounced at lateral and anterior margins of valve. Region of median flattening or shallow sulcus present. Hinge line straight, ranging from two thirds to three quarters of maximum width. Ears poorly developed or absent. Ventral umbo not prominent, being flattened by small umbonal cicatrix. Ventral interarea distinct, bisected by small delthyrium filled by triangular, gently convex or almost flat, pseudodeltidium.

Exterior ornamentation of ventral valve consists of spines and well-spaced concentric growth lamellae. Spines numerous (up to 35 per cm^2), being fine, elongate, suberect, arranged quincuncially on juvenile and submature ontogenetic stages, becoming slightly coarser and concentrically arranged on anterior of mature valves. Anteriorly, spine bases become elongated, may be up to 1 mm in diameter. Dorsal valve also carries concentric lamellae and fine spines, finer than those of ventral valve. Dorsal spines arranged in concentric rows. Dorsal valve exterior also with fine, closely spaced, elongate dimples.

Ventral teeth strong, divergent. On either side of teeth, marginal ridge present, stepped-down from hinge; it persists only a few millimetres past alar extremities. Ventral adductor muscle impressions elongate, smooth; diductor scars longitudinally striated, large, flabellate, extend further anteriorly than adductor marks.

Dorsal valve flattish or gently concave if transverse or moderately concave if more elongate; low median fold rarely present. Dorsal valve strongly geniculate anteriorly with geniculation angle being large, often close to right angle. Internal visceral disc flattish or gently convex. Dorsal interarea with small chilidium. Dorsal adductor scars smooth, split by median septum so that each triangular shaped. Each scar raised anteriorly, level with the interior surface posteriorly. Brachial ridges distinct. Cardinal process strong, erect, extends behind hinge, coplanar with dorsal interarea. Cardinal process trilobed to quadrilobed interiorly, depending on strength of groove dividing prominent median lobe; lateral lobes small. Process arises from junction of median septum, which is thin and about two-thirds valve length, and pair of marginal ridges which run laterally at small angle to hinge. Marginal ridge flattened near alar extremities, becomes more prominent laterally and anteriorly, encircles visceral disc.

Discussion: The above description is based on large collections from the type section of the Noonkanbah Formation. Coleman's (1957) specimens from the Cundlego and Wandagee Formations conform well with the material at hand, particularly in details of the fine body spines and the cluster of fine spines over the poorly-developed ears (Coleman 1957, pl. 18, figs 11, 12).

W. colemani is distinguished from *W. multispinifera* by its more subquadrate outline, coarser ventral spines, generally more concave dorsal valve and coarser dorsal dimples that are more widely spaced.

The relatively flat dorsal valve of transverse *W. multispinifera* and the fine ventral spines recall those of *W. unispinosa* Waterhouse (1969, pl. 9, figs 1, 8), the type

speeies of *Arcticalosia* Waterhouse (1986a), from Aretie Canada, whieh also possesses a shallow ventral suleus and low dorsal fold on somc speeimens. However the fine ventral spines of *W. unispinosa* are elosely spaced and the ears of the speeies are more elearly developed than those of *W. multispinifera.*

Wyndhamia? sp. A
Fig. 3 N–O

Material, Locality and Age: GSWAF 11048, 11049, onc incomplete mould of a dorsal valve interior and one external mould of a dorsal valve and ventral interarea, from 4.8 km west of Arrino township (sce map in Edgell 1965, pl. 33), from Mingenew Formation, Perth Basin. Early Baigendzhinian (Middle Artinskian).

Measurements: In mm. e=estimate.

Specimen Number	Maximum width	Hinge width	Ventral height	Dorsal height
GSWAF 11048	40.0e	25.0e	–	–
GSWAF 11049	37.0	26.0	30.0	25.5

Description: Shell outline transversely oval with hinge line being over two-thirds maximum shell width. Ventral interarea distinct, carries small pseudodeltidium. Dorsal valve exterior apparently smooth but one or two small pustules may indieate spine bases or be artifacts of worn dorsal exterior before preservation. Dorsal interior earries short, stout median septum arising from base of eardinal proeess and continuing anteriorly, biseeting adduetor sears similar to thosc of *W. colemani* sp. nov., but not eontinuing anteriorly of adductor scars. Marginal ridge and brachial ridges developed posteriorly (anterior of dorsal interior not known). Sockets deep, wide, subparallel to hinge line; eardinal proeess erect, poorly known. Dorsal valve genieulated into distinet trail.

Discussion: Assignment of the speeimens to *Wyndhamia* is provisional. Indieations are that the dorsal valve is thickened and somewhat wedge-shaped but the evidence for dorsal spines is equivocal. However, dorsal spines are easily lost through slight deeortication. Alternatively, assignment of the speeimens to *Strophalosia* may be required. The short dorsal median septum, if aeeurately preserved, would indicate that the species is distinet from other Western Australian *Wyndhamia* speeies.

Genus **Lialosia** Muir-Wood and Cooper, 1960

Type Species: *Strophalosia kimberleyensis* Prendergast (1943) from the Grant Range, Noonkanbah Formation, Canning Basin.

Diagnosis: Shell hemispherical to subquadrate, coneavo-convex, with low interareas. Ventral valve with small cicatrix, coneentric lamellae, faint eapillation and row of low hinge spines. Dorsal valve with no spines. Ventral valve with strong teeth and thickened interior. Dorsal interior with strong cardinal proeess, distinet median septum; valve geniculated anteriorly.

Discussion: *Lialosia* was well deseribed by Muir-Wood and Cooper (1960). A full description of the type species is provided below and additional illustrations are provided hercin beeause the species has not been fully illustrated from throughout its stratigraphical range.

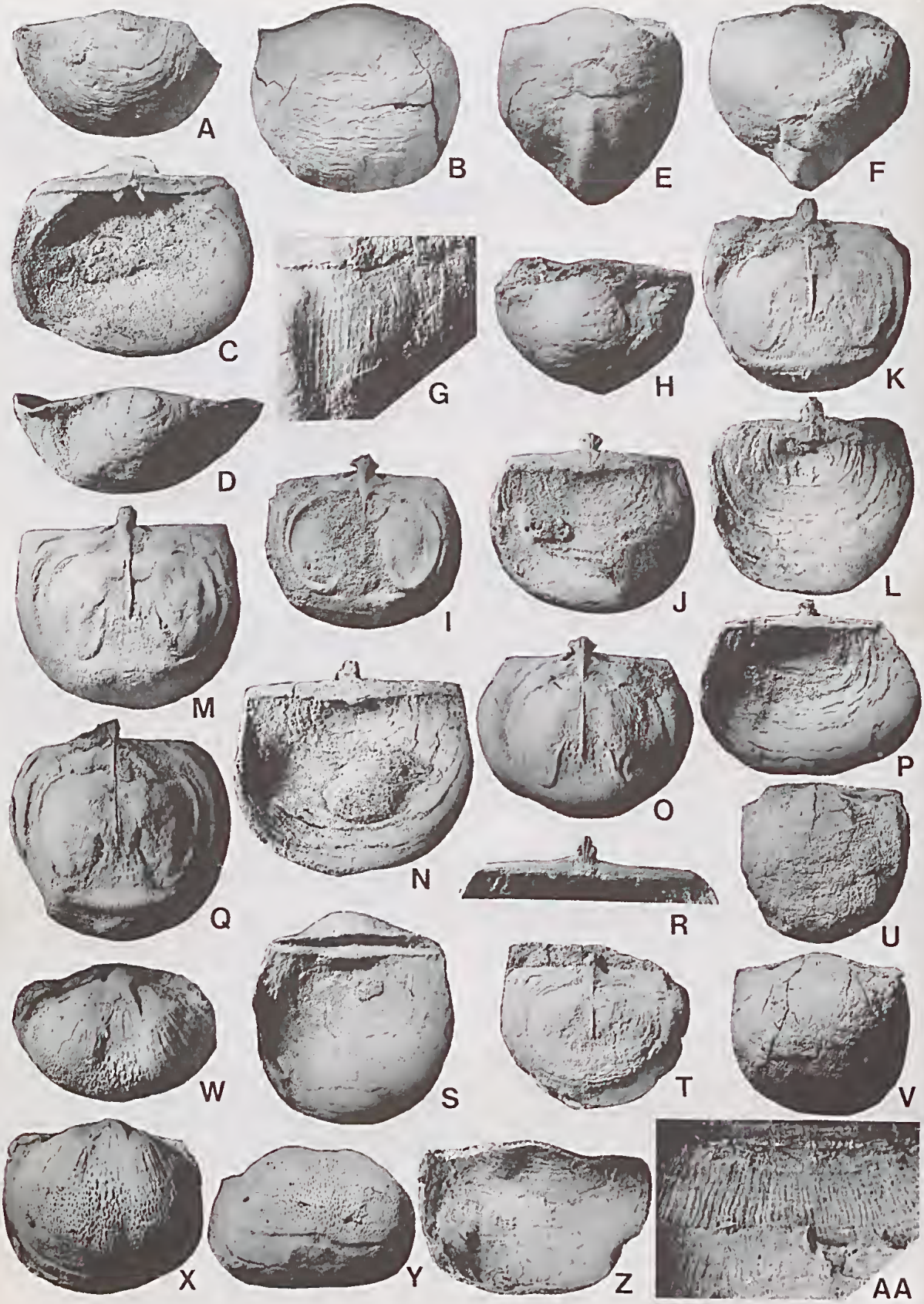
Muir-Wood and Cooper (1960, p. 87) tentatively ineluded *Productus clarkei* Etheridge (1872) in the genus, presumably beeause Foord (1890) originally eompared and referred specimens of *Lialosia kimberleyensis* to Etheridge's speeies. The redeseription of Etheridge's speeies by Maxwell (1954) and additional comments by Waterhouse (1969) and Dear (1971) indieate that the species is a respresentative of *Wyndhamia* and hence is not elose to *Lialosia.*

Lialosia has also been reported from Tastubian faunas of South Tibet (Ching *et al.* 1977, Ching 1979), Baigendzhinian/Early Kungurian faunas of Timor (Waterhouse 1973) and, with a query, faunas assigned to the Dorashamian from Nepal (Waterhouse 1978, 1983).

Lialosia sp. from the Tastubian Jilong Formation of South Tibet (Ching *et al.* 1977, pl. 1, figs 7-9, 22; Ching 1979, pl. 2, figs 5-8; Jin 1985, pl. 1, figs 7, 10-11) is based on small shells that lack external body spines but possess a lamellose and faintly eapillate external ornament. The shells appear not to be thickened, unlike those of *L. kimberleyensis,* but are possibly immature. Further material is required to eonfirm the generic identity and espeeially the internal struetures.

In a review of South East Asian Permian braehiopod correlations, Waterhouse (1973a, p. 194) mentioned the oeeurrenee of *Lialosia* in the Bitauni fauna of Timor. No species was mentioned. *Chonetes dubia* Hamlet (1928, p. 12, pl. 1, figs 11–14) appears to be a representative of *Lialosia* and was described by Hamlet as oecurring at Bitauni and Noil Toko in Timor. Through the courtesy of Dr. C. F. Winkler Prins (Rijksmuseum van Geologie and Mineralogie, Leidcn) I have been sent a series of photographs of Hamlet's speeies. External ornamentation is poorly preserved but hinge spines are present, body spines absent and the dorsal valve is capillate with a few eoarse lamellae. The shells are strongly thiekened although internal details are not known. *Chonetes dubia* is now assigned to *Lialosia* and represents the most reliable occurrenee of the genus outside of Western Australia. Hamlet's species had previously been assigned by me (Arehbold 1981, p. 125; 1983a, p. 70) to *Neochonetes (Sommeriella),* largely on the basis of its transverse outline, shallow sulcus and eapillate dorsal valve as illustrated in Hamlet (pl. 1, fig. 14b).

The ?*Lialosia ovata* of Waterhouse (1983, see also Waterhouse 1978, p. 63, pl. 7, figs 17-20), from faunas of Nepal attributed to the Dorashamian by Waterhouse (1978, 1983), based on two speeimens, is precluded from *Lialosia* by the presence of rare body spines over the disc near the margin of the ventral valve (Waterhouse 1978, p. 63). Braehial ridges of the Nepalese speeies appear to be much morc elongate than those of *L. kimberleyensis* and ventral muscle scars are weakly impressed on the Nepalese species. Body spines are absent on the type species of *Lialosia* and hence ?*Lialosia ovata* is exeluded from the genus. The presence of body spines also excludes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Lialosia (?) *shadrovskiyi* Ustritskiy (1984, p. 114, pl. 6, figs 2–5); from the Kazanian of Novaya Zemlya, from the genus.

Lialosa kimberleyensis (Prendergast, 1943)
Fig. 5 A-Z, AA

1890 *Strophalosia clarkei*: Foord, p. 103, pl. 5, figs 7-8.
1903 *Strophalosia* sp. ind., Etheridge, p. 20, pl. 1, figs 10-12.
1926 *Strophalosia* sp., Glauert, p. 46.
1943 *Strophalosia kimberleyensis* Prendergast, p. 47, pl. 6, figs 1-5.
1957 *Strophalosia (Heteralosia) kimberleyensis* Prendergast, Coleman, p. 124, pl. 20, figs 7-19.
1958 *Strophalosia (Heteralosia) kimberleyensis* Prendergast, Guppy *et al.*, p. 48.
1960 *Lialosia kimberleyensis* (Prendergast) Muir-Wood and Cooper, p. 81, pl. 4, figs 14-24.
1961 *Strophalosia (Heteralosia) kimberleyensis* Prendergast, Dickins, p. 286.
1967 *Strophalosia (Heteralosia) kimberleyensis* Prendergast, Condon, pp. 169, 173.
1975 *Strophalosia (Heteralosia) kimberleyensis* Prendergast, Playford *et al.*, p. 287.

Holotype: UWA 20452, a complete shell, from north of Hill C, south side of Grant Range, West Kimberley District, Noonkanbah Formation, Canning Basin.

Material, Localities and Age: Specimens as figured and measured in addition to abundant material from the Wandagee Formation and Nalbia Sandstone (Carnarvon Basin) and Noonkanbah Formation (Canning Basin) in the collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. CPC 24418, 24419, 26435, 3 dorsal valves from BMR locality KNF 76B, 7 km on a bearing of 298° from Bruten's Old Yard, Cherrabun Station, type section of Noonkanbah Formation, about 357 m above base of Formation. CPC 26433, 26434, 2 ventral valves from BMR locality KNF 88, 4.5 km at a bearing of 310° from Bruten's Old Yard, Cherrabun Station, 369 m above base of type section of Noonkanbah Formation. All from Canning Basin.

CPC 26436, 26437, 1 ventral and 1 dorsal valve from BMR locality ML 45, Minilya River, south bank, 5.5 km west of southwest of Cundlego Well, Wandagee Formation. CPC 26441, 26442, 1 dorsal and 1 ventral valve from BMR locality ML 51, Minilya River, north side, Minilya Syneline, 5 km west of Cundlego Pool, Nalbia Sandstone. CPC 26438–26440, 2 dorsal valves and 1 shell from BMR locality MG 178, approx. 2 km east of Wandagee Hill, Wandagee Formation. CPC 26443, 1 internal mould of a ventral valve from BMR locality F 17018, near Paddy's Outeamp, about 65 m below the top of the Wandagee Formation. CPC 24410, a ventral valve from BMR locality ML 52, Minilya River, north side, Minilya Syneline, 5 km west of Cundlego Well, Nalbia Sandstone. CPC 24421, an external mould of a ventral valve, from BMR locality F 17010, locality 48, traverse northwest of Paddy's Outeamp, Baker Formation. All from Carnarvon Basin.

Noonkanbah and Wandagee occurrences are late Baigendzhinian (Late Artinskian). Nalbia and Baker occurrences are Early Kungurian.

Size Ranges: A total of 32 specimens (including the figured specimens) were measured. Hinge width, 15.6–28.0 mm; maximum width, 19.3–32.0 mm; ventral valve height, 17.5–32.5 mm; dorsal valve height, 16.2–28.1 mm; thickness, 7.2–16.0 mm; ventral valve interarea height, 2.6–4.7 mm; dorsal valve interarea height, 1.4–2.9 mm; dorsal septum length, 7.8–13.2 mm.

Diagnosis: Hemispherical to subquadrate *Lialosia*. Interareas relatively low. Cicatrix normally small, rarely distinct. External ornament of concentric lamellae, more pronounced on dorsal valve, faint capillation and row of ventral hinge spines. Spines absent elsewhere.

Description: Shell of moderate size, outline hemispherical to subquadrate. Ventral valve strongly convex, convexity being even in transverse and longitudinal directions. Ventral sulcus or median flattening of ventral valve not present. One aberrant specimen (CPC 26434) possesses an anteriorly-developed narrow ventral fold which arises anteriorly of major shell breakage (sustained during life), hence probably reflects result of internal damage to animal with consequent aberrant repair and growth of shell. Hinge line straight, hinge itself being over three-quarters maximum width of shell, latter being at midlength of shell.

Ears poorly developed, hinge region does not extend beyond lateral margins of shell. Alar regions rounded. Ventral umbo low, indistinct, does not extend over ventral interarea. Cicatrix of attachment normally minute, frequently not visible; largest cicatrix measured (CPC 26436) distinct and prominent (width 4.9 mm, length 3.5 mm) indicating degree of variability in size. Ventral interarea distinct, moderately high; bisected by narrow

Fig. 5—A-Z, AA, *Lialosia kimberleyensis* (Prendergast). A-B, E-N, From Noonkanbah Formation, Canning Basin; C-D, O-S, W-Y, from Wandagee Formation, Carnarvon Basin; T-V, from Nalbia Sandstone, Carnarvon Basin; Z-AA, from Baker Formation, Carnarvon Basin. A-B, CPC 26433, ventral valve in posterior and ventral views, ×1.2. C-D, CPC 26436, ventral valve in dorsal and posterior views, ×1.5. E-H, CPC 26434, ventral valve in ventral, postero-ventral, portion of surface enlarged and posterior views, all ×1.2 except for enlargement ×4.5. I-J, CPC 24419, dorsal valve in interior and dorsal views, ×1.4. K-L, CPC 24418, dorsal valve in interior and dorsal views, ×1.3. M-N, CPC 26435, dorsal valve in interior and dorsal views, ×1.2. O-P, CPC 26438, dorsal valve in interior and dorsal views, ×1.2. Q, CPC 26439, dorsal valve interior view, ×1.2. R, CPC 26437, dorsal valve in posterior view, ×1.8. S, CPC 26440, shell in dorsal view, ×1.0. T, CPC 26441, dorsal valve interior view, ×1.3. U, CPC 26442, ventral valve in ventral view, ×1.0. V, CPC 24420, ventral valve in ventral view, ×1. W-Y, CPC 26443, ventral valve internal mould in posterior, ventral and anterior views, ×1.2. Z-AA, CPC 24421, external mould of ventral valve and portion of mould enlarged, ×1.2 and ×4.5.

triangular delthyrium filled by convex pseudodeltidium. Ventral interarea striated parallel to hinge line.

Exterior ornamentation of ventral valve consists of single row of relatively fine hinge spines, at low angle to hinge and directed laterally. Distinct, concentric growth lamellae, growth lines and, on well preserved specimens, fine radial capillae present. Spines not thicker than 0.5 mm at base, spaced at about 2–3 mm intervals, the interval increasing away from umbo. Radial capillae fine (about 3 per mm), extend over more than one growth lamellae, but not continuous over entire valve.

Exterior ornament of dorsal valve consists of distinct growth lamellae, fine growth lines, fine radial capillae and, rarely, fine, scattered, shallow dimples. Spines absent.

Ventral teeth strong, robust, divergent. Shell thickened laterally accentuating deep visceral cavity. Distinct marginal ridge arises close to teeth, just below level of interarea; encircles valve in mature specimens; it isolates internal alar extremities resulting in internally demarcated ears although externally poorly demarcated. Adductor muscle scars smooth, elongate, on gently raised platform; bisected by delicate median ridge. Diductor scars large, flabellate, posteriorly smooth, anteriorly densely longitudinally striated; extend further anteriorly than adductor scars. Remainder of valve interior covered with minute pustules except for marginal ridge and short trail which are smooth.

Dorsal valve strongly geniculated with geniculated angle being curved up to 70° from anterior of gently concave visceral disc. Exterior geniculation not abrupt although an increase in concavity noticeable anteriorly. Dorsal interarea low, striated parallel to hinge line. Interarea bisected by small, flat to gently convex, triangular chilidium. Dorsal adductor scars smooth, bisected by median septum. Anterior components of adductor scars gently raised above level of visceral disc, posterior components appear depressed. Brachial ridges distinct, arise from posteriorly-developed internal ridge originating as two short lateral ridges at base of cardinal process. Therefore posterior extremities of brachial ridges appear to enclose adductor scars. Brachial ridges semi-circular, hook back sharply at anterior extremities. Region of brachial ridges smooth. Cardinal process strong, erect; it extends behind hinge line, co-planar with dorsal interarea, at a small angle to plane of visceral disc. Cardinal process appears quadrilobed in mature individuals from both aspects. Prominent median lobe divided by groove in both aspects, small lateral lobes may project widely from central lobe. Process of submature valves appears trilobate interiorly because median groove not developed on central lobe. Cardinal process arises from strongly-developed median septum and from two small lateral ridges that are at small angle to hinge and are anterior to deep, narrow sockets. Marginal ridge arises adjacent to sockets, in mature specimens encircles visceral disc. Internal geniculation of dorsal valve occurs immediately to anterior of marginal ridge. Median septum sharp, high, extends anteriorly for half to almost two-thirds valve length. Valve finely pustulose between brachial ridges, smooth on trail.

Discussion: The above description, based on a diverse collection of often well-preserved specimens, clarifies minor details left unclear by the descriptions of Prendergast (1943), Coleman (1957) and Muir-Wood and Cooper (1960), particularly with regard to the external capillate ornament and the variation in the size of the cicatrix.

Other reports of *Lialosia* are discussed above within the generic discussion. Only *Lialosia dubia* (Hamlet 1928) requires comment here and the Timor species is readily distinguished from *L. kimberleyensis* by its more transverse outline, subquadrate anterior margin, coarser ventral hinge spine bases and less lamellose dorsal valve.

Genus **Liveringia** gen. nov.

=strophalosiid gen. nov. B, Archbold and Thomas, 1986b.

Etymology: From Liveringa Ridge, Canning Basin (Lat. 17°56′S; Long. 124°06′E).

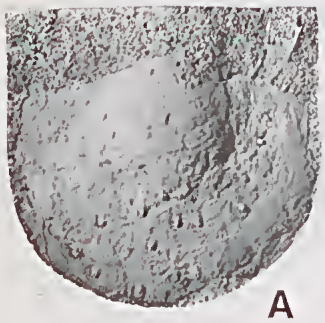
Type Species: *Liveringia magnifica* sp. nov.

Diagnosis: Large strophalosiids. Cicatrix apparently absent. Ventral valve exterior with prominent row of long curved spines on hinge and ears; rest of valve sparsely spinose except for anterior of mature valves with fine, erect spines in ill-defined concentric rows. Ventral adductor scars elongate, smooth, may be bisected posteriorly by low median ridge. Ventral diductor scars large, radially striated, relatively weakly impressed. Dorsal valve with shallow elongate dimples arranged in quincunx posteriorly, less regular anteriorly. Fine persistent capillae arise within 1 cm of umbo, persist until anterior of valve. No dorsal spines. Growth lines delicate, seldom lamellose. Dorsal interior with strongly-developed brachial ridges, marginal ridge and median septum. Cardinal process, thick shafted, with small, lateral lobes.

Ventral interarea low, dorsal interarea low. Teeth stout, small, either side of small delthyrium, filled with gently convex pseudodeltidium.

Discussion: This large genus is of similar gross dimensions to large species of *Wyndhamia*. *Liveringia* gen. nov. is, however, readily distinguishable from that genus by the absence of dorsal spines and the presence of a dorsal ornament of relatively widely-spaced, elongate dimples and persistent fine capillae. Species of *Strophalosia* can exhibit impersistent capillae and dimples, however, the dimples of *Strophalosia* are not as shallow, elongate or

Fig. 6—A-L, *Liveringia magnifica* gen. et sp. nov., all from Hardman Formation, Canning Basin. A, CPC 26444, ventral valve in ventral view, ×1.6. B-C, CPC 26452, natural cast of dorsal valve in interior and posterior views, ×1.1 and ×2.5 D-E, CPC 24422, ventral valve in ventral and posterior views, ×1.2. F, CPC 26445, latex cast of dorsal valve external mould, ×1.2. G, CPC 24424, dorsal valve in dorsal view, ×2.5. H, CPC 26454, ventral valve internal mould in ventral view, ×1. I, CPC 26446, ventral valve in posterior view, ×1. J, CPC 26453, natural cast of dorsal valve, interior view, ×1. K-L, CPC 26447, ventral valve internal mould in ventral view, ×1.2.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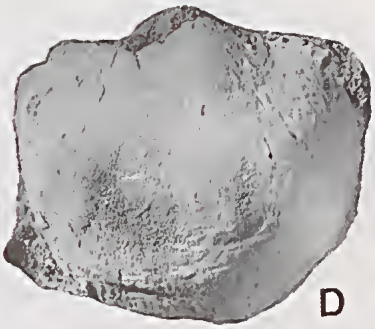
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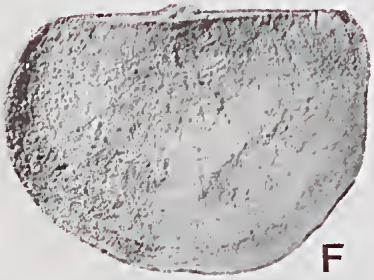
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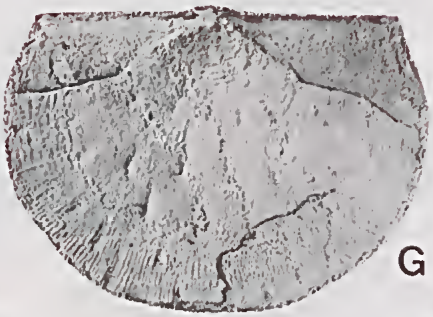
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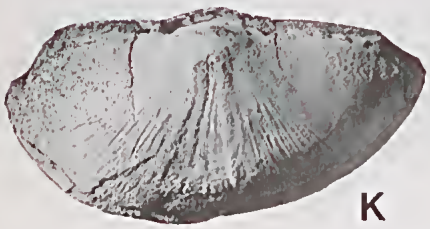
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widely spaced as on the new genus (e.g. see *Strophalosia jimbaensis* Archbold 1986, fig. 2A for an Australian species with well-developed dimples and *Strophalosia tolli* Fredericks, 1931, as figured by Grigor'eva 1977, pl. 3, fig. 15, for a Siberian species with closely spaced, abundant dorsal dimples). Details of ventral spinosity and internal structures also distinguish *Strophalosia* from the new genus. The nature of dorsal exterior dimples on *Wyndhamia* appears variable (as discussed above under *W. colemani*) but seldom are they as widely spaced as on *Liveringia* gen. nov. *W. antarctica* (Frech 1898, pl. 4, figs 9a, 9b) possesses the most widely-spaced dimples of any recorded *Wyndhamia* but apparently lacks any capillae. No other species are assigned to *Liveringia* gen. nov. apart from the type species.

Liveringia magnifica sp. nov.
Figs 6A-L, 7A-L

?1958 *Strophalosia* sp. nov., Guppy *et al.*, p. 54.
1986 Strophalosiid gen. nov. B, Archbold and Thomas, p. 435.

Holotype: CPC 26450, a dorsal valve external mould from near mouth of Nerrima Creek, Canning Basin, Hardman Formation.

Material, Localities and Age: Specimens as figured and measured in addition to abundant material from the Hardman Formation, Canning Basin, in the collections of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. CPC 24423, 24424, 26445-26451, 2 dorsal valves, 3 ventral valves, 2 dorsal valve external moulds and 2 ventral valve internal moulds from BMR locality FL 220, near mouth of Nerrima Creek, 4 km at a bearing of 95° from Luluigui Homestead, Hardman Formation. CPC 24422, 26454, 26455, 1 ventral valve, 1 ventral valve internal mould and 1 incomplete dorsal valve from BMR locality KNB 53, near Andys Well, Noonkanbah Station, about 13 km at a bearing of 47° from Mount Fenton, Hardman Formation. CPC 26453, 26454, 1 natural cast of a dorsal valve and 1 ventral valve internal mould from BMR locality N 1241, Lat. 19°06′39″S, Long. 125°11′27″E. Hardman Formation. All Canning Basin.

All Chhidruan (Early Tatarian).

Size Ranges: A total of 22 specimens (including the figured specimens) were measured. Hinge width, 16.7-44.0 mm; maximum width, 18.7-55.6 mm; ventral valve height 17.8-39.2 mm; dorsal valve height, 13.2-42.9 mm; thickness, 12.0-18.0 mm; ventral interarea height, 2.5 mm (one measurement); dorsal interarea height, 0.6-2.2 mm; dorsal septum length, 15.2-24.5 mm.

Diagnosis: Large transverse *Liveringia,* normally transversely oval in outline. Ventral valve with fine body spines and prominent hinge spines; concentric growth lines weakly developed. Ventral interior with coarsely-striated diductor scars. Dorsal valve exterior with elongate dimples and fine persistent capillae; concentric growth lines feeble, rarely lamellose anteriorly. Ventral and dorsal interareas low.

Description: Shell large, outline normally transversely oval. Ventral valve strongly convex with convexity decreasing towards anterior of valve. Convexity even in transverse direction, no sulcus or median flattening developed. Hinge line straight, hinge being over seven-eighths maximum width in juvenile specimens, decreasing to three-quarters or two-thirds maximum width in mature specimens. Maximum shell width normally at about midlength of shell, although in largest dorsal valve closer to hinge line. Alar extremities rounded with result that ears small, if present, and poorly differentiated. Ventral umbo small, pointed, inconspicuously overhangs ventral interarea. Available specimens show no trace of cicatrix of attachment; ventral umbo being rounded not flattened. Ventral interarea low for size of shells, striated parallel to hinge line. Interarea bisected by small, triangular delthyrium filled with convex pseudodeltidium.

Exterior ornamentation of ventral valve consists of spines, inconspicuous concentric growth lines and traces of fine capillae. Spines developed as row along hinge where they are fine (0.6 mm wide at base on specimen CPC 26451 at 15.5 mm from umbo), long (up to 8.0 mm long on specimen CPC 26446) and curve away from umbo. Body spines fine, scattered over venter (normally removed by wear), subconcentric rows over trail. Trail spines on specimen CPC 26451 are 0.4 to 0.5 mm wide at base, spaced at 1 to 3 mm intervals. Trail and venter spines erect to point anteriorly.

Exterior ornament of dorsal valve consists of elongate dimples, fine radial capillae and delicate growth lines—seldom lamellose. Dimples arranged subquincuncially in juvenile and submature specimens, in concentric rows on anterior of adult specimens. Dimples elongate (2.0 mm long at 2.5 cm from umbo and 1.3 mm long at 7.5 mm from umbo on specimen CPC 26450), narrow (0.4 mm wide—constant width of dimples on CPC 26450) and impressed on interior of juvenile dorsal valves. Row of subcircular dimples occurs across hinge region—corresponding to ventral hinge spines. Capillae fine (5 or 6 per mm), persistent across growth lines; they are evident within 1 cm of umbo. Growth lines fine, inconspicuous posteriorly, rarely lamellose anteriorly; up to 9 occur per mm.

Ventral teeth small, robust, divergent, set close together. Low marginal ridge arises adjacent to teeth extends around perimeter of visceral disc in mature specimens. Adductor muscle scars elongate, slightly raised, smooth and may be bisected by delicate median ridge. Diductor scars large, flabellate, weakly impressed, coarsely radially striate with striae being up to 1.5 mm apart; extend further anteriorly than adductor scars. Remainder of ventral interior striate, minutely pustulose except for marginal ridge and trail which tend to be smooth.

Dorsal valve distinctly concave, strongly geniculate in mature specimens. Dorsal interarea low, striated parallel to hinge line, bisected by narrow notothyrium filled with gently convex chilidium. Interiorly visceral disc gently concave and anterior of mature valve strongly geniculate, angle of geniculation being up to 80° from plane of visceral disc. Dorsal adductor scars smooth, bisected by high median septum. Adductor scars differentiated into

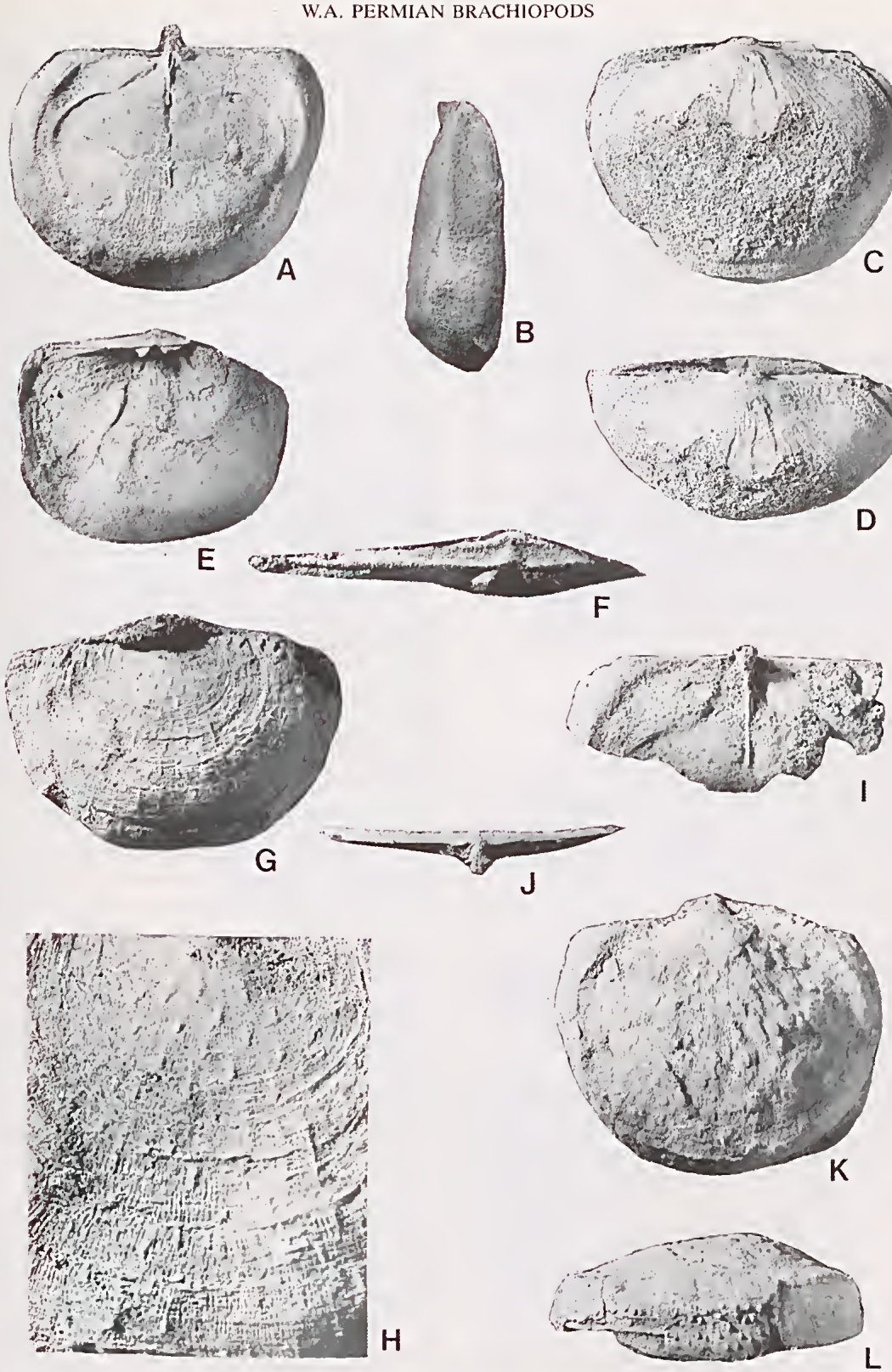

Fig. 7—A-L, *Liveringia magnifica* gen. et sp. nov, all from Hardman Formation, Canning Basin. A-B, CPC 24423, dorsal valve in interior and lateral views, ×1. C-D, CPC 26448, ventral valve internal mould in ventral and posterior views, ×1.2. E-F, CPC 26449, latex cast of internal mould of ventral valve and interarea enlarged, ×1 and ×2.5. G-H, CPC 26450, holotype, dorsal valve external mould, ×1.2 and portion of mould enlarged, ×3.2. I-J, CPC 26455, incomplete dorsal valve in interior and posterior views, ×1. K-L, CPC 26451, ventral valve in ventral and anterior views, ×1.

anterior and posterior components, weakly impressed. Brachial ridges distinct, low, arise from continuation of two low lateral ridges at base of the cardinal process. Brachial ridges broadly semicircular, hook back sharply at anterior extremities. Cardinal process stout, strong, erect, extends behind hinge for short distance, co-planer with dorsal interarea. Process feebly quadrilobed interiorly in mature specimens when prominent medial lobe bisected by shallow groove; distinctly quadrilobed exteriorly; smaller lateral lobes widely divergent. Process arises from high, strong median septum which extends for less than half valve length, and pair of low, thick lateral ridges that continue anteriorly and give rise to brachial ridges. Pair of lateral ridges surround broad, relatively shallow sockets. Anterior of valve smooth or minutely pitted and pustulose. Prominent marginal ridge arises adjacent to sockets, demarcates perimeter of visceral disc laterally and anteriorly from strongly-geniculated margin of valve.

DISCUSSION: No other known species possesses the combination of characters of *Liveringia maguifica* sp. nov.

Genus **Echinalosia** Waterhouse, 1967

TYPE SPECIES: *Strophalosia maxwelli* Waterhouse, 1964.

DIAGNOSIS AND DISCUSSION: See Archbold (1986, p. 111).

Echinalosia denisoni sp. nov.

1971 *Echinalosia prideri*: Waterhouse, p. 392.
1976 *Echinalosia prideri*: Waterhouse, p. 102.
1978 *Echinalosia* sp. nov., McClung, p. 422.
1982 *Echinalosia prideri*: Waterhouse, p. 31; pl. 23, fig. i; text figs 19A, B. (See for additional synonymy).
1983 *Enchinalosia* sp. nov., McClung, p. 71; fig. 13: 1-12.
1986 *Enchinalosia prideri*: Waterhouse, p. 28.

ETYMOLOGY: From the Denison Trough, Bowen Basin, Queensland.

HOLOTYPE: Specimen GSQ F12465, an external mould of a dorsal valve from GSQ Eddystone 1, interval C, Denison Trough, Queensland. Figured by McClung (1983, p. 71, fig. 13: 12). Housed in collection of the Geological Survey of Queensland, Brisbane.

DIAGNOSIS: Moderate to large *Echinalosia* with elongate outline. Ventral valve strongly convex, apparently without sulcus. Ventral spines long, coarse, scattered to moderately dense. Ventral exterior also with short radial grooves over most of valve. Dorsal valve exterior strongly lamellose, dimpled, with scattered coarse spines essentially confined to valve anterior. Ventral interior thickened with long, wide adductor scars and large elliptical diductor scars. Teeth strong. Dorsal interior with strong sockets, weakly-developed brachial ridges and thin median septum. (Modified from McClung 1973, p. 71.)

DISCUSSION: Reports of *Echinalosia prideri* (Coleman) from New Zealand (Waterhouse 1982) were questioned by Archbold (1986) when reviewing Coleman's species. New Zealand material is sparse and only one specimen, an internal mould of a ventral valve, has been figured (Waterhouse 1982, pl. 23, fig. i). Subsequently, Waterhouse (1986b, p. 28) referred a suite of specimens described and figured by McClung (1983) to *E. prideri*. McClung's (1983) specimens, from the Denison Trough, Bowen Basin, Queensland, represent a distinctive, younger species, probably related to, but separate from *E. prideri* (Coleman) and are here named *E. denisoni* sp. nov. Additional details of the new species are provided by McClung (1983).

E. prideri, well described and illustrated by Coleman (1957), was reviewed by Archbold (1986) who provided additional illustrations. *E. denisoni* sp. nov. is characterised by a denser ventral spine pattern than that of *E. prideri*, a ventral exterior with prominent radial grooves (McClung 1983, fig. 13: 11) and a strongly lamellose dorsal exterior with spines essentially confined to the valve anterior. The dorsal valve of *E. prideri* is lamellose externally (although not as prominent as *E. denisoni* sp. nov.) and carries numerous coarse spines on both the juvenile and mature stages of growth. Interiors of the two species do indicate a possible relationship (Waterhouse 1986b) although brachial ridges are poorly developed in *E. denisoni* sp. nov., perhaps because fully mature specimens are not known.

Both the Queensland and New Zealand occurrences of *E. denisoni* sp. nov. are of Late Artinskian (Late Baigendzhinian) age as discussed by Waterhouse (1982, 1986b). *E. prideri* is, however, Early Baigendzhinian (Late Artinskian) in age and is only known from the Lower Member of the Madeline Formation of the Carnarvon Basin (Condon 1967). Reports of *E. prideri* from the Sterlitamakian Callytharra Formation (Condon 1967, p. 70; Coleman 1957, Table 1 between pages 135 and 136) and the Late Baigendzhinian Cundlego Formation (Coleman 1957, Table 1; Waterhouse 1982) have not been confirmed by later studies. Coleman's original description only mentioned material from the Bulgadoo Shale, and this was subsequently mapped as Madeline Formation.

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